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PERFORMANCE OF RADAR CIRCULATION DETECTION ALGORITHMS: TEXAS TORNADOS 27 MAY 1997

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1. ABSTRACT

Operational Support Facility (OSF) and National Severe Storms Laboratory (NSSL) personnel evaluated performance of the WSR-88D base products, Build 9 Software algorithms, and next generation algorithms for tornadoes in central Texas on May 27, 1997. Three tornadic mesocyclones were investigated: Jarrell, Cedar Park, and Pedernales Valley. Algorithm evaluations were based on Level II data from the Austin/San Antonio area radar (New Branfels, TX; EWX). The Build 9 Mesocyclone Algorithm performed inconsistently in that several 3D correlated shears were detected rather than mesocyclones and two operator identified circulations were not found by the algorithm. The Build 9 TVS algorithm did not trigger during the event. Next generation algorithms identified circulations that WSR-88D algorithms failed to detect and provided additional strength and classification information.

2. STORM EVOLUTION

A series of four storms developed in a high instability/weak shear environment along a pre-existing wind-shift boundary in central Texas on 27 May 1997 (Magsig *et al.* 1998). Two of the storms that produced significant tornado damage occurred within adequate range of the EWX radar to allow analysis of the level II data. Three tornadic mesocyclones were studied which produced significant damage to Jarrell, Cedar Park, and the Pedernales Valley area (near Lake Travis). The Jarrell tornado was the second in a series of three tornadoes associated with the Jarrell storm. The Cedar Park and Pedernales Valley tornadoes were the only two tornadoes reported with the Pedernales Valley storm.

3. WSR-88D ALGORITHMS

Personnel at EWX had lowered values of several algorithm adaptable parameters in response to OSF memoranda issued in 1995 and 1996. The value of minimum 2D feature size, Threshold Patter Vector, was lowered from a default value of ten pattern vectors to a value of eight pattern vectors.

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Figures 1-3 list Build 9 WSR-88D Mesocyclone Algorithm_(B9MA) detections, mesocyclone (M) and three dimensional correlated shear (3D), across the bottom of each graph for 26 of the 29 volume scans. The B9MA missed three circulations: 2043 before the Cedar Park tornado formed, Fig. 2; 2141 and 2147 while the Pedernales Valley tornado was on the ground, Fig. 3. (All times are listed in Universal Time Coordinate.) Forty-three additional circulations were also identified between 2002 and 2210.

Personnel at EWX also lowered the adaptable parameter value of the shear required to identify a TVS, Threshold TVS Shear (TTS), from the default value of 72 hr-1 to 48 hr-1. There were no TVSs detected during the entire event.

4. AN EXPERIMENTAL IMPROVEMENT FOR THE BUILD 9 MESOCYCLONE ALGORITHM.

OSF personnel have developed an experimental improvement to the B9MA called the Integrated Rotational Strength (IRS) index (Lee 1995) based on the mesocyclone recognition nomogram used at National Weather Service Offices (Andra 1997). The strength index is calculated using values of mesocyclone rotational velocity, range, and diameter. The B9MA only locates and classifies 3D features as mesocyclones or 3D correlated shears. The IRS index adds information about the rotational velocity integrated over the depth of each circulation.

Figures 1-3 display the IRS index, scale to left, for each tornadic mesocyclone detected by the B9MA. When the algorithm failed to detect a circulation, an IRS value could not be calculated. The median IRS value for the 26 identified tornadic circulations was 7.0 and the median IRS value for the 43 other circulations was 3.3.

5. NSSL EXPERIMENTAL ALGORITHMS

Level II data and the WSR-88D Algorithm Testing and Display System (WATADS) (McKibben *et al.* 1996) were used to assess the performance of NSSL's experimental algorithms. Mesocyclone and tornado algorithm detections were compared to observed tornadic circulations.

The NSSL Mesocyclone Detection Algorithm (MDA)

(Stumpf and Witt 1998) identified circulations before the B9MA. Because MDA was designed to classify and quantify all circulations, many more detections were processed compared to the B9MA. MDA detected 174 3D features during the 29 volume scans investigated and did not miss any circulations while tornadoes were observed.

Figures 1-3 show MDA strength rank, scale to right, plotted against time for 25 of the 29 volume scans. The strength rank is based on circulation range and shear. (Stumpf and Witt 1998) The median strength rank of the 25 tornadic circulations was five and the median strength rank of the 149 other circulations was two.

MDA also uses a neural network to assess Probability Of Tornado (POT) for each circulation detected. POT values for each circulation are shown across the bottom of each graph in Figs. 1-3. Eleven of the 25 mesocyclone detections had POT values greater than 50% and only two other circulations between 2002 and 2210, not shown, had POT values greater than 50%.

The NSSL Tornado Detection Algorithm (TDA) (Mitchell and Vasiloff 1998) triggered 11 times during the three mesocyclones studied. There were also four TDA detections classified as apparent false alarms on other storms not examined here.

6. DISCUSSION

Tornadic circulations formed quickly on the forward flank of the storm, relative to the highly deviate S-SW storm motion, and the B9MA identified the circulations immediately. Unfortunately, rapid mesocyclone intensification precluded even the experimental algorithms from identifying strong circulations long before tornadoes formed.

The B9MA classified 11 circulations out of the 26 detections as 3D correlated shears instead of mesocyclones. A mesocyclone is defined within the B9MA as a 3D circulation containing two or more 2D features that meet an aspect ratio or symmetry criteria. A 3D correlated shear meets all mesocyclone criteria except for the requirement that it contain at least two symmetric 2D features. As the tornadic circulations formed, they were strong and deep, but slightly elongated. Some of the 2D features failed the symmetry test and 3D correlated shears, rather than mesocyclones, were identified. When the adaptable parameter that controls the near-range aspect ratio was changed from two to three, six of the 11 3D correlated shears were reclassified as mesocyclones. When the same parameter was changed to four, all detections except one were reclassifed as mesocycones.

The B9MA missed two significant circulations during the Pedernales Valley event, Fig 3. When adaptable parameter values of minimum 2D feature size and pattern vector momentum and shear were reduced, both circulations were identified; however, algorithm performance over the 29 volume scans decreased because the total number of algorithm detections increased significantly. The NSSL MDA had no trouble detecting these two circulations.

The WSR-88D TVS Algorithm failed to trigger even when a minimum TVS Shear value of 48 hr-1 was used. Subsequent investigations revealed that the TVS algorithm failed to trigger because the TTS adaptable parameter value was too high. When the shear value was lowered to 36 hr-1, the TVS algorithm triggered on two of the Pedernales Valley tornadic circulations. When the shear value was lowered to 18 hr-1, the TVS algorithm triggered on four of the 29 tornadic circulations but also generated three apparent false alarms.

7. CONCLUSIONS

The WSR-88D radar base products provided insight into the severity of the event. Weak echo regions were observed and operator identified mesocyclone signatures coincided with both storms before and during tornadic events. Velocity dealiasing errors did not prevent forecasters from recognizing mesocyclone development, but the errors negatively impacted Mesocyclone and TVS Algorithm processing.

The B9MA correctly identified circulations on the first volume scan of each storm that contained an obvious rotational signature in the storm relative velocity data. However, elliptical shear caused the algorithm to classify meosocyclonic circulations as 3D correlated shear. When the near-range aspect ratio adaptable parameter was increased, 3D correlated shears were reclassified as mesocyclones.

OSF personnel modified the 2D feature aspect ratio, minimum 2D feature size, velocity momentum value, and TVS shear value to study several algorithm failures. When the B9MA default adaptable parameters were tested, seven out of 29 circulations were missed and 30 additional circulations were identified. The adaptable parameter changes made by EWX personnel improved the performance of the B9MA in that the number of circulations missed dropped from seven to three at the expense of adding 13 false alarms over the 128 minute time period. When adaptable parameters were lowered to detect all tornadic circulations, the number of false detections increased considerably.

The NSSL MDA strength rank and OSF experimental IRS index help forecasters classify circulations. These new algorithm concepts improve upon the first generation algorithms which only attempt to detect mesocyclonic circulations.

The NSSL next generation algorithms identified many more circulations, but they also correctly identified many of the tornadic circulations with mesocyclone and TVS signatures. With WSR-88D software Build 10, forecasters will be able to use the new NSSL Tornado Detection

Algorithm. In subsequent software releases, mesocyclone classification schemes (Probability of Tornado, strength rank, and others) will help forecasters identify dangerous circulations.

There are at least three lessons that forecasters can learn from this event: (1) the performance of the current Mesocyclone and TVS Algorithms can be improved by lowering several adaptable parameter values (see sections 3 and 6), (2) algorithm detections labeled 3D correlated shear are not necessarily weaker or less dangerous than mesocyclone detections, and (3) when storm relative velocity products indicate rotation associated with convection having a history of tornadic development in a highly unstable environment, do not wait for algorithm confirmation of strong, deep rotation because tornadoes may form quickly.

8. ACKNOWLEDGMENTS

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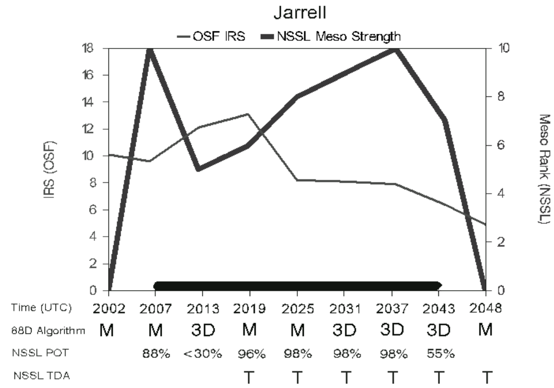

Figure 1.

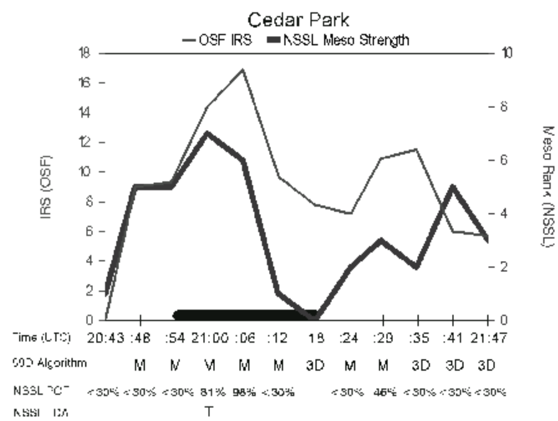

Figure 2.

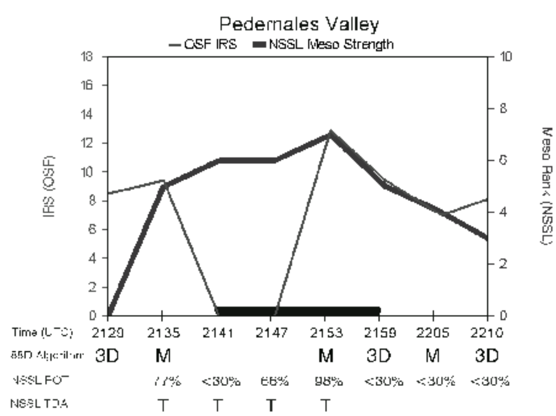

Figure 3.